Unsupervised deep learning for super-resolution reconstruction of turbulence

Year: 2020 | Citations: 266 | Authors: Hyojin Kim, Junhyuk Kim, Sungjin Won, Changhoon Lee

---

Abstract

Abstract Recent attempts to use deep learning for super-resolution reconstruction of turbulent flows have used supervised learning, which requires paired data for training. This limitation hinders more practical applications of super-resolution reconstruction. Therefore, we present an unsupervised learning model that adopts a cycle-consistent generative adversarial network (CycleGAN) that can be trained with unpaired turbulence data for super-resolution reconstruction. Our model is validated using three examples: (i) recovering the original flow field from filtered data using direct numerical simulation (DNS) of homogeneous isotropic turbulence; (ii) reconstructing full-resolution fields using partially measured data from the DNS of turbulent channel flows; and (iii) generating a DNS-resolution flow field from large-eddy simulation (LES) data for turbulent channel flows. In examples (i) and (ii), for which paired data are available for supervised learning, our unsupervised model demonstrates qualitatively and quantitatively similar performance as that of the best supervised learning model. More importantly, in example (iii), where supervised learning is impossible, our model successfully reconstructs the high-resolution flow field of statistical DNS quality from the LES data. Furthermore, we find that the present model has almost universal applicability to all values of Reynolds numbers within the tested range. This demonstrates that unsupervised learning of turbulence data is indeed possible, opening a new door for the wide application of super-resolution reconstruction of turbulent fields.